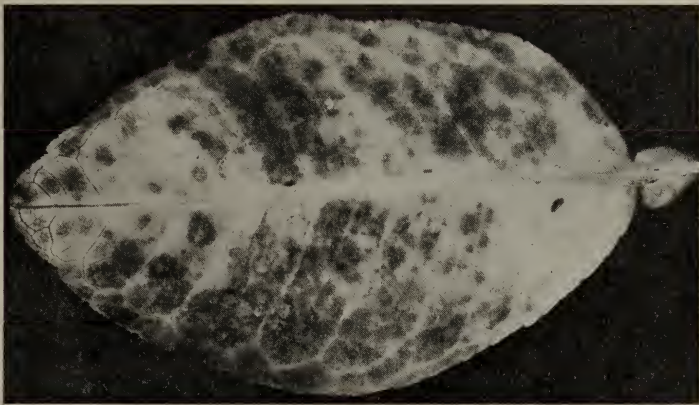


COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

SPRAYING WITH DISTILLATES.

By W. H. VOLCK.



LEAF SPOTTED WITH DISTILLATE.

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SPRAYING WITH DISTILLATES.

INTRODUCTORY NOTE.—The “spotting” of oranges results in considerable losses to growers of this fruit, and many causes have been assigned as producing it. Some of these alleged causes certainly have no relation to the trouble at all. Spots can be produced by mechanical injury, or by chemicals used to kill insects. Commonly one can readily distinguish between the spots due to either friction, fumigation, or distillate spraying; and can also distinguish these from spots caused in other ways. Growers usually fail to realize the possibility of a variety of causes, and assign the whole difficulty to one or another of the real or supposed sources of the trouble.

Spraying with distillates has probably caused more loss by spotting than any other one thing.

The study of this subject was first undertaken by this Station some two years ago. Further studies and observations of the results of field operations were made last summer, and finally in connection with the study of the red spider of citrus trees, reported in Bulletin No. 145, Mr. Volck was able to bring out of the work the conclusions presented in the following pages. This Bulletin, therefore, may be considered as in part representing further results of the coöperation between the Los Angeles County Board of Horticultural Commissioners and the Entomological Department of the Experiment Station of the University of California. Mr. Volck has opened the way to a much clearer appreciation of the problems of distillate spraying than has heretofore existed.

C. W. WOODWORTH.

In sections where the refined distillation products derived from crude petroleum are used as insecticides, it is common to speak of spraying with “distillate” as though referring to a single definite substance. But such a wide range of oils and preparations of oils are used, that this may be very misleading; since an opinion based upon the results of any one of them would not by any means apply to all. It would be less confusing, therefore, to speak of these products in the plural sense as distillates.

The term “distillates,” when applied to petroleum products, refers to any oils derived from crude oil by distillation. Crude oils are obtained from wells tapping natural reservoirs of petroleum in the rocks. The oils obtained from different wells may vary in a marked degree in their composition, but most Western oils differ from the Eastern petroleum, and resemble each other to the extent that they contain asphaltum instead of paraffin as their solid base. If any of these oils are placed in a retort and distilled, the distillates will be driven off in the form of vapor, which condenses into oil on cooling. This first distillation retains considerable asphaltum and has a dark color. It is known as “green” or raw distillate. If the green distillate is now redistilled and

the oil condensed while the retort is heating to successively higher temperatures, a set of oils can be successively collected corresponding to their different boiling points.

These oils correspond to definite chemical compounds with successively larger amounts of carbon, but are not sharply defined; since a heavier oil will begin to pass over before all the lighter oil has evaporated. In most refined products there is more or less a mixture of light and heavy oils. These oils belong to the benzine series; but each thus contains other oils of the same series and is charged with greater or less quantities of other substances occurring as impurities. To remove these substances the oils may be treated with sulfuric acid, then with caustic soda, and finally filtered through sawdust to remove water and water-soluble materials, after which they are called "treated distillates."

The naphtha and kerosene obtained by distillation of Western oils are not often used as spraying materials, although kerosene might be used advantageously in some cases. Likewise the heavy lubricating oils are not regarded as suitable for spraying. The distillates most used are those approximating 28° gravity (28° Baumé), and there is some disposition to use as low as 26° gravity. These oils lie between the kerosenes and the lubricating oils, and have some of the properties of each. They dry more slowly than kerosene, have a characteristic odor, and when clarified range from nearly white to a deep yellowish-brown color.

The accompanying table of analyses, made by Mr. Colby of this Station, shows the composition of some of these distillates.

There are two ways in which 28° distillate may be prepared: first, by mixing oils of higher and lower gravity; and second, by direct distillation—the so-called short-cut method.

The *short-cut distillate* resembles the mixed oils in containing oils of both higher and lower gravities, but there is less range; by far the greater part of the oil corresponds closely to the gravity indicated, and in the case of 28° gravity may be considered a nearly pure "gas distillate." The short-cut process for the production of spraying distillates is used much more now than formerly.

TABLE I. COMPOSITION OF "GAS DISTILLATES." By G. E. COLEY.

	"GAS DISTILLATES" FROM LOS ANGELES REFINERIES.					FROM SAN FRANCISCO REFINERIES.	
						"Gas Distillate."	"Petroleum Distillate."
Manufacturer, or sender.---	Densmore-Stabler Co	Southern Refining Co.	The Asphalt Refining Co.	Hercules Refining Co.	Franklin Refining Co.	W. P. Fuller & Co.	Paraffine Paint Co.
Color -----	Brown.	Blue.	Light brown	Green.	Black.	Brown.	Light brown.
<i>Analysis.</i>							
Degrees Baumé-----	26	26	28.5	25	27	29	27
Gasoline.-----	<i>Per Ct.</i> None	<i>Per Ct.</i> None	<i>Per Ct.</i> None	<i>Per Ct.</i> None	<i>Per Ct.</i> None	<i>Per Ct.</i> None	<i>Per Ct.</i> None
Benzine.-----	None	None	None	None	None	None	None
Naphtha.-----	3.1	1.2	None	1.2	1.5	None	1.6
Illuminating Oils-----	26.5	45.4	89.00	28.1	53.1	None	13.1
"Gas Distillate" -----	22.5	37.2	6.20	29.3	17.5	75.00	8.3
Lubricating Oils -----	46.1	14.7	4.63	39.3	26.6	23.80	74.3
Asphalt-----	1.8	1.5	.17	2.1	1.3	1.20	2.7
Totals -----	100.0	100.0	100.0	100.0	100.0	100.00	100.0

These results show that only one of the above, viz., No. 112, is probably a true gas distillate containing none of the light kerosene, benzine, and naphtha products, while all of the others contain from 14.5 to 89 per cent of these light products of distillation. They may be considered as *crude oils*, or mixtures of light and heavy oils, so blended as to have approximately a gravity of 28° Baumé.—G. E. C.

Method of Use.—The most practical way to use oils as insecticides is to dilute them with water. This is rather a difficult matter to accomplish, since oil will not dissolve in water. Various methods have been devised to accomplish the mixing of water and oil. These may be divided into two classes, the emulsions and the mechanical mixtures.

Emulsions.—The mechanical mixing idea antedated the emulsions, but as first handled it was unsatisfactory, owing to the imperfect nature of the machinery used. In order to overcome the disadvantages of the mechanical process two forms of soap emulsions were devised, one by Professor A. J. Cook, and another by Professor C. V. Riley and his assistant, Mr. Hubbard. Eastern kerosene was employed, and for a long time this was the only oil used in spraying.

Kerosene emulsions, when prepared with care, are stable and very satisfactory as spraying materials; they have had wide application in the East, and to a less extent also on this Coast. The relatively high cost of this oil limits its availability as an insecticide.

In recent years, with a view of obtaining a cheaper insecticide, many other oils have been tried, notably California distillates; but it was at once observed that the light kerosenes prepared from these Western oils did not emulsify well, and when used on the trunk of the tree in large quantities for scale insects, the separated oil often accumulated at the surface of the ground and resulted injuriously. This difficulty was partly overcome by using heavier oils, and gas distillate of 28° Baumé became quite generally adopted.

The emulsions made from California oils have not usually been as satisfactory as those from Eastern kerosene, and a large amount of damage has been done by separated oil, which rises to the surface in the spraying tanks. The desire of the sprayers to be economical of material causes them, when the tank gets low, to finally spray this separated oil onto the trees.

Permanent emulsions are prepared by breaking the oil up into fine particles in a fluid which has sufficient surface tension to prevent them from readily uniting together. The small size of the droplets decreases the natural tendency of the oil to rise to the surface. When milk is used as an emulsifier a compound emulsion is produced, the casein particles coating the oil globules.

Soap is the cheapest, and therefore ordinarily the best emulsifying material. Soaps differ much in their emulsifying properties. Whale-oil soap usually gives very satisfactory results, as do also certain vegetable soaps. In place of these, common laundry soap, which is cheaper, may be used. The standard formula for kerosene emulsion is:

	Riley.	Cook.
Soap.....	½ pound	½ pound
Water.....	1 gallon	1 gallon
Oil.....	2 gallons	1 quart
Dilute with water, after emulsifying, to	30 gallons	4 gallons

With 28° or 26° distillates a pound of soap (dissolved in a gallon of water) to a gallon of oil gives good results. In preparing the emulsion the soap is dissolved in the water by boiling, and the oil is added while this spray solution is hot; the whole being churned very vigorously until the emulsion is formed.

Other emulsifying materials have been used, such as sour milk, and the juice of such plants as the soap plant (*Chlorogalum*).

But the preparation of stable emulsions is a difficult matter and it will not be necessary to go deeply into the subject in this bulletin, as they have largely been superseded by mechanical mixing methods.

The emulsions have proved unsatisfactory, primarily because of the difficulty of obtaining a stable article. If the oil separates and rises to the surface and is then pumped on the foliage in a pure state, great injury may result; in fact, the largest part of the serious injury to trees credited to distillate sprays may be traced to the bad effects of the separated oil.

Mechanical Mixtures.—While the mechanical mixing idea preceded the emulsions, it is only in recent years that it has been perfected and made practicable. There are several types of machinery which may be used to form mechanical emulsions, but they all operate to break up the oil into fine particles and keep it suspended in water by some kind of agitation. All such methods require the constant use of power to keep the oil and water mixed. In several spray outfits the entire body of the oil and water carried into the field is rotated or churned by means of a paddle working at such a speed that the oil is mixed with the water and broken up into such small particles that the mixture looks milky. This mechanical emulsion is then pumped through the nozzles and applied as a spray.

In other machines the oil and water are carried in separate tanks and mixed in the process of pumping. The oil and water may be drawn into a single pump and the proportions regulated by valves; or separate pumps of different sizes may be used. With this system a baffling chamber or cylinder is sometimes used. In the baffling chamber obstructions are placed, so that when the mixture is passed through it there is considerable friction, which is intended to bring about a more perfect emulsion.

Mechanical mixing represents the most modern idea in practical spraying, and is certainly a great improvement over the "stable" emulsions, which were so only in name.

In the case of citrus fruits there is another reason why the mechanical mixtures are superior to stable emulsions. The spotting of the fruit, which is due to the accumulation of oil by the drying of the large drops which form on the under side of the orange, is noticeably greater with these emulsions.

The oil in the latter is practically all held in the drop until the water evaporates, when the emulsion breaks down and the distillate penetrates the rind. In the mechanically mixed drop, however, the oil separates more quickly and seems to spread out over a relatively greater surface, and for this reason may not do much damage.

OILS AS INSECTICIDES.

The distillates are not the only oils having insecticidal properties; in fact, nearly all oils are capable of killing insects; but it is the volatile oils that are most effective, their vapors having far greater penetrating power than the oils in the liquid form. Death by suffocation, due to the clogging of the breathing pores of the insect, is only possible with the heavier and more slowly-drying oils, and death in this manner even with these is only a matter of conjecture. Commercial distillates contain a wide range of oils so brought together as to make up their definite degree of gravity. Some of the heavy oils found in the distillate may be very slow-drying, while the lighter parts will be correspondingly volatile.

This mixture of oils is apparently more effective than the pure volatile products, which may be explained on the ground that the heavy oils prevent the too rapid dissipation of the volatile parts. While the vapor is doubtless the condition in which oils exhibit their more evident insecticidal effect, the oils are certainly most effective when the liquid comes in immediate contact with the insect. The vapor given off by oil which has been sprayed on parts of the tree not infested with insects is usually too much, or too diluted by the air, to be effective on the parts that are infested.

Insects capable of motions show signs of great irritation and weakness when brought into contact with small particles of a volatile oil. But if the dose has not been too large, recovery always takes place.

The black scale, which is stationary during the greater part of its life, is not capable of exhibiting other symptoms of the effect of an oil than the loosening of the insect's grasp on the tree, so that it will "slip" much more easily than when not affected. This loosening is noticeable a few minutes after spraying, and is possibly due to two causes: the weakening of the insect itself, causing the muscles of the labium to relax, and the softening of the gummy matter which the insect secretes under its body and which helps to hold it to the tree. With this insect also, recovery may take place, and insects which are quite loose soon after spraying will often regain their hold.

It is possible, by increasing the amount of oil applied, to arrive at a point where all insects will be killed; but the difference in the resistance of the insects and the plants infested by them may not be great enough in some cases to allow the use of oil without danger to the plant.

PENETRATION OF OILS INTO THE PLANT.

By far the greatest cause of injury to vegetable tissues is brought about by the penetration of the oils applied, into the interior of the plant. Any one who has examined carefully a plant which has recently been sprayed with a distillate, especially one made of the heavy oils, will notice blotch-like spots beneath the surface which are somewhat darker than the surrounding tissues. (See frontispiece.) These spots are evidently due to the presence of oil which has penetrated the tissue of the plant, and owing to its slight volatility this may remain for weeks or even months.

Leaf Structure.—The rate of the penetration of a fluid into the leaf from the surface largely depends on the presence of appreciable openings through which it may pass, and when this fluid is in limited quantities other factors enter—such as the surface tension of the fluid itself, and the distribution of the oil on the leaf. Sometimes the surface of a leaf is smooth and free from hairs, as is seen in the guava and orange; while in other cases it is covered with a more or less dense growth of hairs, as in the morning-glory and quince. If a drop of oil is placed on an orange leaf it will not spread greatly over the surface, but if the same drop were placed on a morning-glory leaf the hairs would act as a wick, spreading the drop out over a considerable area. If the morning-glory leaves were as resistant to oils as are the orange leaves the injury would be far less.

If a drop of oil is placed on the upper and lower surface of an orange leaf it will be seen that the one on the lower surface will soak through the epidermis, while that on the upper surface will often remain until it evaporates. If the epidermis of the leaf is examined under the microscope, the upper one will show a comparatively smooth and unbroken surface, while the lower epidermis will be found closely sprinkled with openings known as *stomata*. A stoma is not a simple opening, but is provided with a valve-like arrangement of cells around it, which expand and contract according to the amount of moisture within the leaf and the relative humidity of the air. The presence of these stomata easily explains, then, the greater penetration through the lower epidermis.

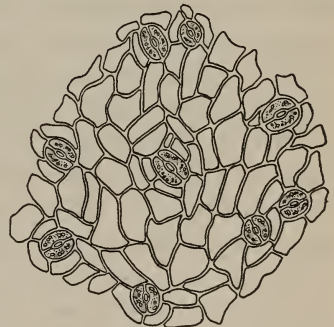


FIG. 1. A fragment of the lower epidermis of an orange leaf, showing stomata.

Again, if a drop of oil is placed on an orange leaf and the epidermis under it is punctured by a needle or other sharp instrument the oil will flow in very rapidly, showing that any injury to the surface of the leaf

may help the oil to gain entrance. If this experiment is performed at the same time on the upper and lower surfaces it will be seen that as the oil spreads beneath the epidermis, forming regular patches with the point of entrance as a center, the patch on the lower surface will spread much faster than that on the upper one. The explanation of this is found in the structure of the inside of the leaf. (Fig. 2.)

Generally speaking, a section of a leaf at right angles to the upper and lower surfaces will show the cells to be arranged after the following

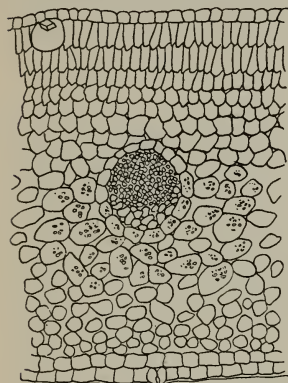


FIG. 2. Showing the internal structure of an orange leaf and a cross-section of a vascular bundle.

plan: The upper surface is made up of a row of light-colored cells—the *epidermis*. These are thin-walled and empty in the case of the leaves of citrus trees. Beneath this is a layer of closely packed, elongated, and somewhat pointed green cells, arranged with their points toward the surface layer, or crosswise, of the section. These are known as the *palisade cells*, and in combination form the *palisade layer*. Under the palisade layer is a layer of large, irregular cells, which are loosely joined together, leaving spaces and passages between them. These cells are also green, but paler than the palisade layer. They constitute what is known as the *spongy layer*. The spongy

layer extends to the lower epidermis of the leaf. The tightly packed palisade layer on the upper side gives little space for the spread of oil, but below this the loose structure of the spongy layer furnishes just the right sort of passageway for the rapid spread of the oils.

Aside from the green parts of the leaf there is the framework of *vascular bundles*, constituting the ribs and veins, which in some cases, notably the orange and guava (see Fig. 2), are buried within the layers of green cells; while in others, as the apricot (see Fig. 3), peach, and morning-glory, the vascular bundles connect with the epidermis both above and below. The vascular bundles are woody and compact structures, very different from the rest of the leaf. In the orange leaf the veins offer little resistance to the flow of the oil; but this is not the case with such a leaf as that of the morning-glory or apricot, where the vascular bundles uniting closely with the epidermis very effectively impede the flow of oil from one part of the tissue to another.

Diffusion of Oil.—This structural difference in leaves is a very important factor in the toxic effect of oils. Thus, for instance, in the orange leaf a drop of oil entering at one point may become diffused, spreading over so large an area that it may volatilize so soon as to cause little injury. On the other hand, in an apricot leaf, the oil being restricted

by the vascular net to a small area, the same-sized drop will do injury before it can evaporate. With the apricot and morning-glory the penetrated parts are usually killed, the line of killing being irregular and following the vascular bundles.

It should be mentioned in this connection that the structure of the fruit rind of citrus fruits is in some particulars much the same as that of the leaf, there being stomata sprinkled over the surface, with green cell tissue beneath. Distillate penetrates the rind, and if a heavy oil, it remains for a long time, if not indefinitely, and thus forms the much-talked-of spotting.

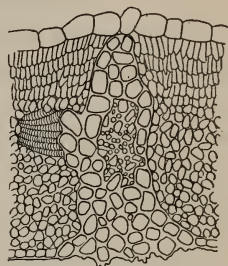


FIG. 3. Showing a cross-section of a vascular bundle of an apricot leaf.

Returning to the diffusion of oil through an uninterrupted spongy layer, it is evident that the capillarity of the oil must have much to do with the amount of the spread. The viscosity also, which tends to act against the capillarity by increasing the time required for a given body of oil to pass through a capillary opening, has its effect on the spreading. This is well illustrated by placing a drop of kerosene and a drop of a lubricating oil upon the same leaf; the kerosene quickly diffuses through the cell structure, while the lubricator acts much more slowly and never spreads as far. Thus the heavy oils, in addition to their slow drying, aggravate the difficulty by remaining locally concentrated.

Condition of the Plant.—Aside from simple points of structure, the condition of the leaf greatly affects the behavior of oils toward it. The flowing of oil through the cell interspaces is quite a different thing from the penetration of the cells themselves, or even the complete isolation of the individual cells, both of which must occur to some extent in the penetration of oils beneath the epidermis. Generally speaking, oil can not take the place of water, therefore an active cell well filled with water would be least likely to suffer in this way. But cells which are partly dried out and whose surfaces have become dry may be penetrated or sealed over by the oil. Thus the mechanical effects of oils are often sufficient to render parts of sprayed leaves functionless. If this isolation lasts long, it is alone sufficient to account for a large amount of the injury due to distillates. The age and health of the plant and leaf largely determine the amount or extent of the conditions which affect penetration. The older a leaf becomes, the rougher the skin and greater the probability of having received injuries. But the extreme young leaves, on the other hand, are more liable to be completely covered by a film of oil, and so killed. The old leaves are much drier and therefore more penetrable, and consequently suffer

most if they receive the same treatment as do the younger leaves. However, on the tree such leaves are often so protected by the outside newer ones that in practice they often escape. In general, old leaves are most affected and the natural falling process much hastened.

CONDITIONS AFFECTING THE AMOUNT OF INJURY.

The greatest need for further work with oils is to determine their effect on plants under carefully determined conditions. A beginning has been made along a number of lines, but only that which has clearly led to definite conclusions can be now reported.

Quantity of Oil.—In order to determine more accurately the effect of oils on the plant, small quantities of oil were measured off and applied to leaves of definite sizes.

The branches chosen for the experiment were what are known as water-sprouts. These grow larger leaves than the fruiting branches and give a greater number on the same twig, which can be utilized for checks and experiments.

The practice was to begin with the lower leaves and work toward the tip of the branch, first applying a definite amount of oil to the under side of a leaf, then to the upper side of the next leaf, and, lastly, the same amount of oil was spread over both surfaces of a similar leaf. This operation was usually repeated three times on a sprout, and check leaves were left all along the stem. The data of two of these tests are as follows:

TABLE II. EXPERIMENTS ON LEAVES WITH DIFFERENT AMOUNTS OF OIL.

Eastern Kerosene. Applied November 28th.

Leaf No.	Area of each side of Leaf Surface.	QUANTITY OF OIL USED.		Amount of Yellowing.	Date of Falling.
		Upper Surface.	Lower Surface.		
1	68.76 sq. cm.	---	.12 cc.	slight	-----
2	73.84 "	.12 cc.	---	slight	-----
3	81.53 "	.06	.06	slight	-----
4	57.69 "	---	.12	slight	-----
5	58.45 "	.12	---	slight	-----
6	56.66 "	.06	.06	slight	-----
7	42.92 "	---	.06	-----	-----
8	46.66 "	.06	---	-----	-----
9	38.35 "	.03	.03	-----	-----

Short-cut 28° Distillate. Applied November 19th.

1	69.23 sq. cm.	---	.05 cc.	slight	-----
2	70.30 "	.05 cc.	---	-----	-----
3	70.00 "	.025	.025	-----	Nov. 27
4	56.61 "	---	.05	-----	Nov. 27
5	51.57 "	.05	---	-----	-----
6	51.07 "	.025	.025	-----	Nov. 28
7	47.76 "	---	.05	-----	Nov. 28
8	42.79 "	.05	---	-----	-----
9	39.69 "	.025	.025	noticeable	-----

These experiments were repeated a number of times with various oils and dilutions, and brought out the following results:

First—The upper surfaces of the leaves were always able to resist amounts of oil which proved fatal when applied to the lower surface of corresponding leaves; but the oil applied to the upper surface had some effect, and often caused a slight yellowing of the leaves.

Second—When the same amount of oil as was used on a single surface was spread over both surfaces of a similar leaf it often caused the falling of the leaf.

Third—When the whole amount of oil was placed on the under side of the leaves, the result was about the same as when the oil was placed on both surfaces, causing falling and yellowing where similar amounts applied to the upper surface only were but slightly injurious.

It was often noticed that the large leaves near the base of the water-sprout showed serious effects from amounts of oil which the smaller and younger leaves at the tip resisted. This can be explained by the fact that these older leaves absorbed the oil much more readily, owing to their drier and rougher epidermis, while the young leaves were quite resistant to penetration and better supplied with water.

Character of the Oils.—Experiments were made to ascertain the effects of oil of different gravities. The oils were diluted to definite per cents with water in a bottle and shaken up until well mixed, when the mechanical emulsions, before they had time to separate, were poured over small branches. It was found that, among the oils tried under these conditions, the Eastern kerosene was the least injurious to the foliage, and that the amount of injury for a given per cent increased very rapidly with the gravity of the oil. Kerosene was found to produce no apparent injury on orange at 10 per cent, while the heavier oils were not free from injury at 2 per cent. It was also shown that orange foliage is much more resistant than that of the apricot.

The above experiments also illustrated, in a very interesting manner, the effect of *oils of different gravity*. The two records will serve to show the comparative effect of a 28° gravity distillate and Eastern kerosene. By comparing the preceding table it will be seen that for leaves of the same area and age an amount of *kerosene*, which was as large as the leaves could retain on their surfaces, was far less injurious than the much smaller amounts of *28° gravity distillate*. This heavy oil was manufactured by the short-cut process and said to be especially pure.

The *spray distillates* prepared by several refining companies were tried in the same way and showed similar results. There has been much contention in favor of clarified oils for spraying, but in our experiments little difference was found in them, except that the vapor of certain unclarified distillates proved more injurious to orange foliage than that from the best grade of short-cut clarified oils. This, as shown

by direct experiments, is not due to any asphaltum or nitrogenous materials, but to benzines and volatile oils contained in the less pure products.

In our experience the injuries resulting from distillates are not due to any impurities contained in the oils, but to the oils themselves, and the only way to diminish these injuries is to choose less injurious oils, which evidently lie toward the kerosenes. Pure Eastern kerosene has given the best results, but certain cheap Western kerosenes have proved quite satisfactory. These can be obtained at nearly the same price as the clarified 28° gravity oils, so the only increase in the expense that would result would be the greater amounts of these oils required to be effective.

The Effects of Mixed Oils.—Some sprayers add turpentine and other light oils to the heavy distillates to enhance their insecticidal properties. The effects of the mixed oils on the plant are in general very nearly the average of the effects produced by these oils used independently, though the addition of 10 per cent turpentine to the 28° B. oil used does not materially change the result. Turpentine when used alone produces marked local injury and quick killing of affected parts, but has slight chronic effect, owing to its rapid evaporation. When mixed with the heavy oils, turpentine does not show these local effects in dilutions of 10 per cent or less.

If kerosene and the heavy oils are mixed, the moderating effect of the former is soon noticed. This is well shown by the following experiment; but as the branches experimented with had to be taken on different trees, the results are not in perfect ratio to the per cent indicated: Mixtures of kerosene and Southern Refining Company's 28° B. (short-cut) distillate, varying from 1 to 100 per cent, were applied to thirty-three branches of Valencia orange trees on the 22d of November, 1902. The branches were chosen in nearly the same position on the trees, and all were in about the same condition of fruit and foliage. The dilution was 4 per cent. On the 26th of December, 1902, the branches were all removed and arranged in the order of the apparent injury resulting.

Beginning with the most normal samples the per cents of kerosene in the mixture read 100, 90, 80, 70, 60, 30, 32, 34, 26, 28, 50, 24, 19, 18, 20, 19, 16, 15, 17, 10, 12, 11, 13, 14, 9, 1, 6, 5, 8, 7, 3, 4, 2.

The effects of the applications varied from almost nothing with pure kerosene to serious defoliation and loss of color with the lower per cents, showing clearly the injurious effects of the heavy oils.

General and Local Injury.—Along with the quantitative work a series of experiments were made to determine the *parts of the plant* where oils

can do the greatest injury. With the citrus tree, leaves often break off at the junction of petiole and blade without showing any other signs of injury. It would seem from this that the injury was done at or near this point; but that this is not the case was shown by many experiments.

In one set of experiments oils and vaselines were applied to the petiole and blade at and near the point of juncture, but falling did not take place, although the doses used were often strong enough to kill the soft green pulp.

In a second set of experiments large areas at the base of the leaves were treated successively with oils, both upper and lower surfaces, and lower surface alone. In these experiments, while the parts covered with oil soon became yellow, the leaves did not fall unless the area covered was at least half of that of the whole leaf; but the same effect was obtained by coating the outer half of the leaf.

These experiments were repeated often enough to give perfectly definite demonstration, and they show that the most important injuries caused by oils are general and not local.

In the same way oils were applied to twigs and petioles, without coating the leaves. Here the leaves remained sound, but fermentations were set up in the stem which caused the production of gum; and very marked gum disease can, therefore, be produced by oiling the stems with a slow-drying oil like vaseline.

METHODS OF APPLICATION.

The different methods of applying oils and the results are illustrated in the accompanying figures (Fig. 4).

From the small experiments mentioned above, it was seen that the upper side of a leaf is several times more resistant to oils than the lower surface; some experiments were therefore conducted with a view of applying this principle in spraying.

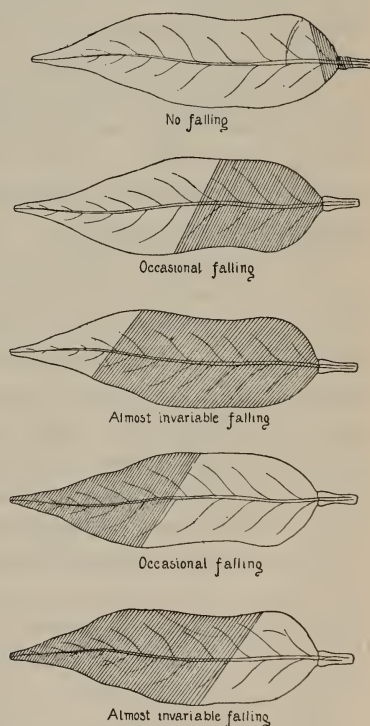


FIG. 4. The shading indicates portions covered with oil.

Overshot and Undershot Spraying.—It may prove convenient to use the term “overshot” for downward spraying, and “undershot” for spraying

upward. If emulsions or mechanically mixed oils are sprayed on the tree, always directing the nozzle downward, the upper surfaces of the leaves will be wet together with considerable more than half the surface of the branches, for the applied liquid runs around the twigs and branches, often completely wetting them.

Large branches of orange and grape-fruit were sprayed as described above with various 28° gravity distillates, a dilution of 4.5 per cent being used. Other similar branches were sprayed with the same dilution from beneath, throwing the spray only on the under side of the leaves. Still others were sprayed in the ordinary manner; that is, both from above and beneath.

These experiments were repeated a number of times with similar results, as follows: In all overshot work the foliage was very little injured, and in all undershot and normal spraying the injury was very serious.

All the branches sprayed were well infested with black scale, and it was found that the overshot method killed quite as many as would be killed by normal spraying with 1.5 to 2 per cent doses, which are as great as the tree can stand.

The effect of overshot spraying on the fruit is not as promising as that on the foliage, as the large drops which run down from the upper surface are liable to spot the rind. This difficulty may be greatly obviated in practice by the methods described in the chapter on Practical Suggestions, on page 25.

The *duration of application* is all-important with the oils. This is due to the method of diluting with water a body insoluble in the latter, which, as has already been stated, consists in breaking up the oils into fine particles held apart by the water of dilution. As oils are sticky or adhesive in their nature, the small particles tend to attach themselves to solid bodies with which they come in contact. For example, the continued application of a 1 per cent dilution of oil to a branch for ten minutes might result in leaving as much oil on the exposed surface as a dilution of 10 per cent applied for one minute.

The *manner of application* further implies the force and method used. It is clear that a spray thrown against the plant with considerable force will penetrate more than one which strikes lightly. Mist sprays are for this reason theoretically best for distillate work, but the nature of the foliage may modify this in practice.

With water-dilution of oils, it is impossible to get an even distribution of the oil over the surface, as the water collects in drops, and the contained oil is deposited in spots. Thus it may happen that an amount of oil too small to penetrate if spread evenly over the surface will do so when concentrated on small spots.

In this connection, some experimenting was done with a method of applying the oil free from water by means of an *air blast*. Here the diluting material was air; and consequently a particle of oil which landed on any part of the plant, did not change its position unless an excess was used, when running together took place. In this way, the maximum of oil can be applied to a given leaf surface without penetration.

Influence of Weather Conditions.—The *humidity* of the air largely determines the extent to which the stomata, or breathing pores, are open, and thus may influence the penetration of oils. In general, the stomata are more open in moist weather than in dry. They are, however, largely closed in very dry air, but here the extreme dryness of the leaf surface and of the pore openings lend themselves to the adhesion and inflow of the oils; so a dry day may not be as good a time to spray with distillates as one moderately moist.

Temperature seems to affect penetration, at least it has a very marked effect on the final results. Theoretically, with higher temperatures the oils are thinner and hence are better adapted to capillary flow. Another potent factor in this connection is that the high temperature in this climate is usually accompanied with low atmospheric humidity, and so adds to the effect of the latter.

NATURE OF INJURY PRODUCED BY OILS.

There are, doubtless, two kinds of injury produced by oils, which we may denominate chemical and physical.

Physical Injuries.—The physical injury from oil is due to insulation or sealing-over of parts of the plant, preventing the access of air to the inclosed parts. Insulation is also of two kinds, external and internal. External insulation consists in coating the outer surface of the leaf, stem, or fruit, as the case may be, with an air- and water-tight covering. If this covering is of a volatile nature it will pass away before any harm results; but if it remains for a considerable time, much of the characteristic injury resulting from the use of the distillate can be obtained with substances of a different nature.

The effect of external insulation would necessarily be of two kinds: first, the *prevention of the loss of water*; and second, the *exclusion of the air*, the oxygen and carbon dioxid of which are essential to plant life.

The *normal loss of water*, or transpiration of a plant is very great, and if interrupted there must result some disorder in the parts affected. The following simple experiments serve to illustrate the point in question:

A set of leaves was taken from a growing plant and part of them coated with vaseline; some on the upper surface only, some on the

lower surface, and the others on both surfaces; all being put in a cool place along with the check or untreated leaves. Observations made from time to time showed considerable difference in behavior. The check leaves soon dried up, and were followed somewhat later by those greased on the upper surface only; while those treated on the under and on both surfaces remained unchanged for a long time; those coated on both sides lasting the longest. Vaseline has been used in several external experiments, but has one objection, viz.: When it is heated up to 80° F., or thereabouts, it is more or less liquid and will penetrate as other oils do. It is, however, a neutral substance and can not, except when very old, exert any chemical effect.

In order to determine the amount of water given off by living leaves treated with vaseline in the above-mentioned ways, they may be inclosed in glass tubes without severing them from the plant, and the amount of condensation of water noted. A record of one such experiment shows the following results: Four orange leaves, each having an area of about 20 sq. cm. on each side of the leaf, were inclosed in test-tubes, two checks and two treated—one coated on the upper surface and one on the lower surface. An examination one week later showed an abundance of condensation water in the check tubes and also in the one containing the leaf treated on the upper surface; but that containing the leaf treated on the lower surface showed only a very slight condensation on the surface of the tube. Twenty days from the beginning of the experiment the tubes were removed and the condensation water measured:

First check.....	0.9 cc.
Second check, dried up since former observation.	
Treated upper surface.....	0.5 cc.
Treated lower surface (fallen from petiole), water not a measurable quantity.	

Results similar to these were obtained in other experiments, and show in a very striking manner the possible effect of distillates on the transpiration of plants.

Insulation experiments were tried with other substances, such as paraffin, plaster-of-paris, etc., and the results agree with those cited above.

The other possible effect of external insulation, namely, exclusion of the air from affected parts, may be demonstrated to some extent by covering ripe fruit with paraffin. Some oranges treated in this way and kept in a cool place along with the checks, showed, after three weeks, a marked souring of the juice. This particular sample at this time showed no decay of the rind. Two weeks later the wax on the remaining sample was much inflated with gas bubbles and the rind showed some fungus decay. The checks meanwhile kept perfectly. The well-known observations on the behavior of plants placed in a nitrogen

atmosphere may be cited in this connection. Strasburger, in his textbook of Botany, describes the effects produced as follows: "By placing them, for example, under a jar containing either pure nitrogen or hydrogen, or in one from which the air has been exhausted, plants previously growing vigorously cease their growth; the streaming motion of protoplasm in the cells is suspended. Motile organs of the plant become stiff and rigid and sink into a death-like condition"; and further, "In every condition of rigor, internal chemical changes take place, which, by a prolonged exclusion of oxygen, lead to the destruction and disorganization of the living substance."

The effect of oils in internal insulation is much the same as in the external, but here individual cells are involved and consequently another source of injury may exist, namely, that of insulation of the cells from one another, which would lead to still further complications.

Internal insulation is a more serious problem in practical spraying than the external, for the reason that it is most liable to occur. Less oil is required to effect a complete covering, because it is protected from evaporation, and hence remains for a long time.

Two distinct kinds of injury result from insulation, and probably correspond to the two effects obtained by exclusion of air, assisted by prevention of transpiration. These injuries may be classed as *rapid* and *chronic*.

The *rapid injuries*, when a neutral substance is used, depend largely on the temperature, and consist, in the citrus plants, of a rapid falling of the leaves affected, without any apparent change in them. In warm weather, 70° to 90° F., this falling takes place in leaves treated with vaseline or paraffin, in from two to three days; but leaves treated in the same way may require two or three weeks to be affected in cool weather, say at 50° to 60° F. This difference may be due to the lack of transpiration, which allows the leaf to become hotter than it would at the same temperature in the normal state, and thus produces a sort of heat-killing. It is possible that the dropping may be brought about in another way. If the air is excluded from the greater part of the leaf, the heat which would normally bring about healthy cell action might cause the production of toxic substances; these would be communicated to the weak cork-forming cells at the base of the stalk and cause their death and desiccation and a consequent formation of the cork layer, resulting in the falling of the leaf.

The *chronic effect* is very different, being much slower. It also brings about a loss of color, a yellowing in the affected parts and consequent lack of growth or other processes, which may result in the fall of the leaf some weeks or months after the application. In the orange, the chronic effect of stem-coating often brings about violent exudation of gum, resembling the gum disease. This effect is also seen occasionally

in ordinary distillate spraying, and is most evident when the spraying has been done in warm weather.

The yellowing is most noticeable in green orange fruit or leaves which have been treated with vaseline. In from three to four days the color of the fruit begins to lighten, and it may, in the course of a month, assume the brightness of the normal ripe fruit.

Chemical Injury by Oils.—The injury which is due to insulation could just as well be produced by *any* substance which would exclude air and retain water; but most oils have a direct chemical effect, induced by their vapor. If a growing plant is inserted into a bottle containing a small amount of oil showing this chemical effect, and the bottle is corked or sealed for several hours in such a way as not to break or harm the branch, the effect of the vapor may be noted. In this connection three tests made with orange foliage are worthy of note. In the first, a saturated gasoline atmosphere was used. Time of application, half an hour. Twenty-four hours later the tips of the leaves nearest the liquid gasoline in the bottom of the bottle were wilted, and later dried out quite white, otherwise the leaves appeared normal; but in about sixty hours a general bleaching was noted. (This was a *whitening* and differed from the yellowing previously referred to.) This bleaching was followed by the falling of all the treated leaves, which was complete in one hundred and twenty hours from the beginning of the experiment.

In the second experiment, Franklin Refining Company's 28° B. distillate was used. The leaves were exposed three and four hours respectively, with similar results. A decided bleaching of the treated foliage was noted in seventy-two hours, accompanied by the falling of the tenderest leaves of the new growth, namely, those just expanded from the bud; later, most of the older leaves fell.

In the third experiment, Southern Refining Company's 28° B. (short-cut) distillate was used. The application lasted five hours, and resulted in a decided bleaching of the lower surface of the leaves, which were also somewhat curled and distorted; but no falling took place.

The results of these experiments are sufficient to show that the chemical effect of oils is entirely different from that of insulation, although it brings about the same ultimate result, namely, the falling of the leaves.

The nature of this chemical effect is not so easy to explain as that of insulation, but it is safe to say that it is always present in spray distillates, although some show it less than others. This is probably the most important insecticidal feature of oils, and it affords the best method of explaining the very marked insecticidal effect of some of them. For instance, in hopper-dozer work it is sufficient that the insect touch the oiled surface with any part of its body in order to bring about

death in a few hours. Insects are probably more subject to the chemical effect of oils than are plants, and may even respond in a different way.

With those oils which contain gasoline, the effect of their vapor on vegetable tissue is rather slow in developing, and partakes of a chronic nature, from which the affected parts recover slowly.

RESISTANCE OF THE PLANT TO INJURY BY OILS.

All plants are not alike in their response to distillates or oils, and the citrus plants were found to be among the most hardy in this respect. There is also considerable difference in the resistance in varieties of the same species. For instance, distillate spraying has long been considered a success on lemons, while it has not succeeded on oranges until the advent of the mechanical mixing process, and is even yet of doubtful utility. Grape-fruit is even more sensitive than the orange. All deciduous trees experimented with have proved very susceptible to injury by the distillates other than kerosene.

The nature of the injury to the orange and apricot foliage also differs somewhat; with apricot, the spots showing penetration were much more localized and the oil in each spot more concentrated, and consequently a withering of parts of leaves occurred, due to the rapid killing of the cells which were entirely surrounded by the oil. This greater localization of oil on the apricot leaf is due to the less penetrable vascular bundles coming in close contact with the epidermis (see Figs. 2 and 3, pp. 12-13), thus making dams which prevent the greater diffusion of penetrated oil, as compared with the orange leaf, where the bundles are buried in the green pulp between the skins. Corresponding doses of distillate are much more injurious to the apricot leaf, as a whole, than to orange foliage, notwithstanding the above-mentioned fact in reference to the localization trouble. In addition to the localized injuries, the leaves of the apricot treated with distillate became yellow, and fell, the petiole breaking from the stem as in the natural falling of an old leaf. The orange leaf, on the other hand, may not show any signs of injury, but will break off at the juncture of petiole and blade in from three to ten days from the time of treatment, falling taking place most and soonest in hot weather.

But injury is not confined to the leaves which drop. All treated leaves are more or less injured and recover very slowly from the effects of the heavy, slow-drying oils. A loss of color may be noted in from ten to fifteen days, and the leaf may never regain its former green appearance. The same dropping and yellowing effect that is seen in the leaves takes place with the fruit also. In fact, the young fruit is much more sensitive than are the leaves to the "dropping" effect of distillates. The yellowing effect is most noticeable in the class of plants to

which the prune and apple belong. The color of the matured leaf may be completely changed in three or four days by the use of very weak dilutions of the 28° distillates, and from what has been observed in these experiments, most deciduous plants, when in leaf, should not be sprayed with the heavy distillates.

Variegated Leaves.—Chronic effects are induced by diseased and depleted conditions of the tree in general. The trouble known as *variegated* leaf was observed to render the trees affected by it quite sensitive to distillates. Also the yellow or dormant condition of the foliage and tree, due to lack of nitrogenous fertilizer, greatly increased the liability of injury from an oily spray material. The old leaves in a normal condition are very sensitive, being drier than the new leaves and in a slow state of vegetative activity. Such leaves will usually fall from any tree sprayed with distillates, a fact which is sometimes cited by sprayers as an advantage of the process; namely, the removal of old and useless foliage. But it must be remembered in this connection, that the cause which effects the falling of some leaves on a tree also operates in the same direction on *every* leaf, with a resulting depressing effect.

Effect of Temperature.—Another and very important feature in the resistance of plants to distillate effects is the temperature of the air. This was dealt with to some extent under the head of penetration, on page 11.

There are two possible ways in which a temperature of about 80° F. might affect leaves treated with distillates. The first relates to the insulation caused by the oils and the consequent checking of transpiration, or the giving-off of water by the plant. It may be roughly likened to a man hard at work and yet unable to perspire. He would soon become overheated and prostrated. In the same way the leaves of a plant might become overheated if the transpiration-current were cut off, except that in the case of the plant the heat must be supplied from the outside.

It has been demonstrated by experiment that insulation will cause the falling of a leaf in two or three days, if the leaf is in the direct sunlight or in a warm location; but leaves treated in the same way and kept in a cool place may remain on the plant for several weeks without change.

The temperature may also affect results by increasing the amount and rate of oil-vaporization, for if the vapor of an oil has any effect it will increase with the amount present, and perhaps this factor is as important as the heat itself.

Aside from the matter of variety, the condition of the plant largely controls its behavior toward distillates. Plants in vigorous growth are

much more resistant than those in a dormant condition. This was constantly noticed in experimenting with the effect of oils. For these reasons distillates are most satisfactory where applied in the cool weather of the fall and winter.

PRACTICAL SUGGESTIONS.

The question of how far the use of an oil spray can be profitably carried with citrus trees depends on its effectiveness when compared with other methods of disinfection. As the spray kills by contact and soon evaporates, the effectiveness of any one operation extends over but a short period. Practically any insect not killed at once, escapes, although there is a slight tendency to chronic injury and slow death, just as in plants.

Repeated experiments and observations of distillate spraying-work done in citrus orchards in southern California have shown that large numbers of insects and mites escape the most careful spraying, and naturally this number increases with the dilution of the wash. In fact, it has been found necessary, in order to avoid serious injury to the trees, to dilute the sprays so much that the hardier and more protected stages of the various scale insects survive in sufficiently large numbers to quickly and completely reinfest the tree, if the treatment stops with one application.

In the case of the *black scale* the evidence in this particular is most complete. The first spraying with a 28° B. distillate of from 2 to 3 per cent dilution results in the death of most of the scales in the active growing stages, often killing scales nearly full grown. The results of such spraying can be determined by inspection in about a week after application. (The few that die later from the effects of the treatment do not affect materially the conclusions reached.) The dead scales will then be shriveled and many will have fallen from the tree. The majority of those living will be found to be old scales covering numerous eggs, which have also remained unaffected. In some cases the old scales may be somewhat loosened, thus aiding the emergence of the young from beneath the shell.

Quite often, an extensive appearance of young scales is noticeable in from two to three weeks after spraying. These and other young, which emerge from time to time, may reinfest the tree, making its condition as serious as ever in from six to seven months after the first spraying. Owing to this fact it is necessary to repeat the spraying two or three times, allowing some months between applications. The operations should be at least two months apart, the object being to reach as many as possible of the insects while still in their more sensitive condition, and to give the tree time to recover from the last spraying. The first spraying may so reduce the number of scales on a tree that all smutting

and injury from this source ceases for the time being, and if the operations are repeated properly will often result in a fairly clean tree.

The *red spider* offers a somewhat different problem. Here the eggs are exposed to the action of the spray, and can be killed with from 1 to 2 per cent dilution of a 28° B. distillate; but in practical spraying many mites escape, presumably those which have not been touched by the spray, and the time which should be allowed to lapse between applications of the spray will often be sufficient for a complete reinfestation of the tree. Thus the control of the mites may be even more doubtful than that of the black scale.

Injury to Plant.—None of these sprayings can be done without more or less injury to the tree and fruit, but there are times of the year and manners of application which make it possible to spray with distillates without this injury being very serious.

The injury caused by distillates to the plant may be briefly summarized as, *first*, the rapid falling of leaves and young fruit, which takes place in from three to ten days after the application; *second*, the yellowing and slower falling of these parts, resulting from the prolonged or chronic effects of the distillate. The rapid falling takes place most and soonest in hot weather, and perhaps the chronic effects are also most felt at this time. The amount of injury resulting from spraying is also much less on healthy trees; that is, trees in good growing condition and not suffering from yellow-leaf, lack of water, or scale. As the amount of water in the plant can be remarkably increased by the watering of the soil, it would seem a good practice in hot weather to spray as soon after irrigation as possible, for at such times the plant would contain most water, and would therefore be less penetrable to distillates. But in general, the results from spring and summer spraying of orange trees have been such as to indicate that the plant will always suffer enough during these seasons to make treatment with distillates inadvisable. Not that the plant in general will be most damaged at such times, but that the young fruit is then most susceptible, both to spotting and dropping.

Spotting and Dropping of Fruit.—There is no doubt that dropping of young fruit is greatly increased by distillate spraying, and may even bring about falling of fruit in sizes which are normally beyond such a possibility. The brown spot or stain which appears on ripe fruit that has been sprayed during the season, is also most liable to be formed when the fruit is young; that is, from half-grown to within a few weeks of coloring. These spots may be noticed in the green fruit as somewhat duller and darker blotches just under the skin of the rind. They do not change much as the fruit grows older, and when coloring takes place they remain brown. Such spots do not injure the orange in any way except appearance.

It is hardly possible to spray with a heavy distillate (that is, 28° B. to 26° B.) without injuring young fruit by spotting or dropping. Then if it is intended to spray with distillates, it is not advisable to do so in the spring or early summer, but the best results will be obtained from October until January. In October the orange rind has developed and is much more difficult to spot than earlier in the season; also the weather is cooler, and the general effects of distillates on the plant are much less severe. Leaf falling will not be so noticeable, and yellowing of the leaves will not be so marked. The fruit is also naturally beginning to color at that time, so any artificial increase in this tendency will not be a detriment.

But it may be argued that the early broods of the black scale will be too large to be killed late in the fall. This would be a greater difficulty if it were not for the fact that most of the early brood die during the summer. It is either parasitized or dies from heat, and also from drought, which may put the tree in such a condition as to kill the scale. In this way the earlier broods of scale are often nearly eliminated from the problem of disinfection.

Two Sprayings Annually.—Now if the problem of fruit injury did not enter into consideration, the spraying in October or November should be followed by a second application at the time the scales, which hatched from the eggs not injured by the first application, had arrived in part at the maximum killable size. This would naturally insure the greatest efficiency to the second operation. But the scales might not reach this condition until well into the growing season of the following spring, when spraying with distillates is inadvisable. The second application should therefore be made in January and February, or just before the flower spurs start. The scales which escape that operation should be left again until October or November, when the routine should be repeated.

This provides for two sprayings a year, and yet may not be sufficient to insure perfectly clean trees; but such can not be obtained by spraying unless the treatment is planned wholly with regard to the scales, and not considering the most desirable time with regard to the plant. Three or four applications will be found necessary to clean badly infested trees and bring the efficiency of this method of disinfection up with that of proper fumigation.

The two sprayings a year, timed as before stated, are not only all that is desirable from the point of plant resistance, but also reaches the limit of the economic advantage which spraying has over fumigation; for experience has shown that *spraying will not be cheaper than fumigation if three or four applications are required.* Further, if a schedule of fall and early spring sprayings is adopted, it will also result in the best control of the red spider which can be obtained with two sprayings.

Where spraying is done early in the season, or during the spring and summer, the spider may be numerous again during the fall and winter, for distillates really leave a large number of mites alive, which by means of their rapid breeding may become abundant again in a few months.

If the spider is abundant in the late spring, early summer, or in the fall, sulfur spraying is advisable before spraying with distillates. The same machinery can be used, but the material will cost more. It is advised by some to use a weak distillate spray in such cases, but it must be remembered that the labor factor is the same as for a full straight dose, and it is not nearly so effective; besides, it is not possible to so reduce the strength of the distillate (28° B. or thereabouts) that it will not affect the plant, and especially the fruit.

PREVENTION OF INJURY FROM SPRAYING.

The question of injury to the plant is one of such serious consequence that any change in the manner or time of application which will reduce the same, is of consequence to those who wish to spray with distillates. Next in importance to the time would come the system used in applying the wash. The method which naturally suggests itself is to wet every part of the tree as thoroughly as possible, so that no insect may escape. In order to do this great care must especially be taken to wet the under side of the leaves. But the experiments detailed above have shown that the under side of a leaf is most sensitive to distillate injury, while the upper side is comparatively resistant. It is obvious that the spray hurled up under the leaves is proportionally much more injurious to the tree than that applied from above.

Overshot Sprays.—The overshot method involves spraying as nearly straight down as possible, beginning with the top of the tree and proceeding toward the sides and bottom. Ladders are necessary to apply this method to large trees, as the sprayer must see what he is doing. With this method it is possible to use about double the per cent of oil without as much injury as results from the ordinary strengths applied in the common way.

The overshot method wets much more than 50 per cent of the stems, but leaves most of the leaves dry on the under side; so if an overshot spraying was done with a 4 per cent dilution, and some ordinary spraying done with 2 per cent, the overshot spraying might kill the greater number of scales and at the same time do less injury to the tree. There are two difficulties in the practical application of the overshot method; first, the spotting of the fruit is not overcome; and second, the red spider, if present, will be left in large numbers on the under side of the leaves.

Whatever may be the chemistry and physics of the commoner form of fruit spot caused by distillates, it is evident that it is produced by

the presence of the oil upon limited areas of the rind. These excessive amounts are large drops of the liquid left hanging to the rind of the fruit after the application has been made. The spots will be somewhat larger than the drops, owing to the spread of the oil beneath the rind. The oil in the drops becomes more and more concentrated by the evaporation of water, and is finally left in a free state on the surface of the rind, from whence it penetrates the tissue. This form of spot will be present to some extent on fruit sprayed by the overshot method. The part of the fruit exposed directly to the action of the spray is wet, and drops of the wash run down the sides and hang from the lower surface. The general surface of the fruit is, however, less injured by overshot spraying than by the ordinary methods.

Combined Spraying.—In view of the spotting and the red spider difficulties which still remain with the overshot method, it is evident that it will have to be supplemented if we would take full advantage of the greater resistance that the upper surfaces of the leaves have to distillates. If the overshot application is followed by a slight undershot spraying with a much weaker dose, the large drops of strong mixture left by the overshot application will be replaced by a much weaker mixture, but still of sufficient strength to kill the red spider. To make this plan successful the undershot application must be made very soon after the overshot, which would require the use of two machines: one to do the overshot work and one to follow doing the undershot. It is possible to modify the types of machines now in use so that both overshot and undershot work can be done by the same outfit.

The existing spraying machines can be modified for overshot work by placing a smaller pump on the piston rod, designed to carry somewhat less than one third the liquid thrown by the large pump. This small pump is connected with the discharge of the large pump and also the water tank by adjustable valves. The discharge of each pump is connected with a separate pressure tank and thence to the hose—the large pump supplies two lines of hose and the small pump one. In operation, part of the mixed water and oil thrown by the large pump is drawn into the small one and again diluted with water from the tank, so that while the large pump might be throwing a dilution of 4 per cent, the small one would deliver a 1 per cent wash, or any other proportions which might be desired. This mechanism overcomes the trouble with the very fine valve adjustment required to introduce 1 per cent of oil directly into the water.

This attachment can be placed on any form of machine. With the double suction patterns the oil is introduced into the large pump, and in the agitator machines an extra water tank must be carried to furnish the water for the small pump. The double suction machines are

evidently best adapted for this attachment, because one water tank serves both purposes.

In this way two lines of hose could be used for the overshot work, applying the spray at from $3\frac{1}{2}$ to 4 per cent oil content, while one line would be occupied with the undershot work, using a 1 per cent wash. The overshot application should be quite thorough, beginning at the top of the tree and extending down the sides, while the undershot operation might consist in rapidly going over the under sides of the fruit to remove the large drops. This would result in a slight wetting of the under side of the foliage, in most cases not enough to result in serious injury. Those who are not provided with such a machine may make some use of the overshot idea by applying most of the wash from above and throwing as little up under the leaves as is possible for thorough work.

There are also some minor points in application which should not be neglected. For instance, an excessive amount should not be applied, for the oil accumulates on the leaves, and the effect of a 4 per cent wash may be had with a 2 per cent dilution. Again, a very dashing, heavy spray will penetrate far more than a fine mist, but the nature of the orange foliage seems to limit the extent to which the mist sprays can be used. This is especially true when the tree is loaded with fruit. All the branches are then bent down and the leaves are held in place by the weight of the fruit. Under these conditions it seems necessary to use a somewhat coarser spray. Spraying outfits usually come equipped with satisfactory nozzles. These are nearly all modifications of the cyclone type. The favorite extension rod has two cyclone nozzles about a foot apart on a cross-arm, which is borne at right angles to the main rod. The nozzles are attached to this rod by means of an elbow. In this way there are no sharp corners or projections to catch in the tree. The nozzles of the Vermorel type, having a plunger for cleaning, are objectionable on this account.

Oil to be Used.—The question of the oil to be used in spraying work is quite important. In the early history of distillate spraying, attempts were made to use much lighter oils than those in more recent practice. At that time the emulsions offered the only means of handling the oils, and it was found very difficult to make very stable emulsions with California light kerosenes, considerable injury being produced by the separated oil. For these reasons heavier oils have been used with better results, so far as emulsions are concerned; but apparently these heavy oils are far worse than the kerosenes in their general effect on the plant.

With Eastern kerosene it was found that 25 per cent of oil was less injurious than 5 per cent of a 28° B. Western distillate. The kerosenes are also somewhat less effective as insecticides, but not in proportion to

their neutrality to plants. This is due to the fact that insects are much more quickly affected than vegetable tissue, and with a volatile oil the plant might escape injury where animal life would be destroyed.

A sample of Western kerosene tried did not give as good results as the Eastern article, but this was probably due to its greater content of benzine and gasoline, which substances are very volatile and severe in their action on plant tissue. But there is no reason why kerosene, sufficiently pure to be used in spraying, could not be prepared by the refining companies at a reasonable cost. Such oils could be used if they could be had for from 8 to 10 cents per gallon. The cost of the heavier distillates ranges from 5 to 7 cents per gallon, and the low per cents used make the expense of the material very small; but it is a question whether the orchardist prefers the cheapest, regardless of consequences. Kerosenes are now quite extensively used in Eastern practice, and the per cents run rather high, 25 per cent of oil content being more common there than 2 per cent with Western distillates.

The orange tree will withstand from 8 to 10 per cent of kerosene, used in ordinary spraying, and 15 per cent in overshot work. These strengths are sufficient to kill young scale and the red spider. Kerosene has the same limitations as the heavier oils, and several applications are required to clean a tree of most insects. It can also be applied to other than citrus plants with greater safety than the heavier distillates. In fact, kerosene oil has many points to commend it to orchardists who wish this kind of an insecticide, but in all cases an article reasonably free from impurities should be insisted upon.

REPORTS AND BULLETINS AVAILABLE FOR DISTRIBUTION.

REPORTS.

- 1896. Report of the Viticultural Work during the seasons 1887-93, with data regarding the Vintages of 1894-95.
- 1897. Resistant Vines, their Selection, Adaptation, and Grafting. Appendix to Viticultural Report for 1896.
- 1898. Partial Report of Work of Agricultural Experiment Station for the years 1895-96 and 1896-97.
- 1900. Report of the Agricultural Experiment Station for the year 1897-98.
- 1902. Report of the Agricultural Experiment Station for 1898-1901.

BULLETINS.

- No. 115. Remedies for Insect and Fungi. (Revised.)
 - 121. The Conservation of Soil Moisture and Economy in the Use of Irrigation Water.
 - 125. Australian Saltbush.
 - 127. Bench-Grafting Resistant Vines.
 - 128. Nature, Value, and Utilization of Alkali Lands.
 - 129. Report of the Condition of Olive Culture in California.
 - 131. The Phylloxera of the Vine.
 - 132. Feeding of Farm Animals.
 - 133. Tolerance of Alkali by Various Cultures.
 - 134. Report of Condition of Vineyards in Portions of Santa Clara Valley.
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 - 140. Lands of the Colorado Delta in Salton Basin, and Supplement.
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 - 142. Grasshoppers in California.
 - 143. California Peach-Tree Borer.
 - 144. The Peach-Worm.
 - 145. The Red Spider of Citrus Trees.
 - 146. New Methods of Grafting and Budding Vines.
 - 147. Culture Work of the Substations.
 - 148. Resistant Vines and their Hybrids.
 - 149. California Sugar Industry.
 - 150. The Value of Oak Leaves for Forage.
 - 151. Arsenical Insecticides.
 - 152. Fumigation Dosage.

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